BEAMFORMING IN CLOSED TEST SECTION

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ABSTRACT

The acoustic test results in the environment like closed test section may interfere with the reflected sources. A series of acoustic test with point source was conducted in KARI low speed wind tunnel with 4mx3m closed test section to find out the reflected source effect. The test was conducted with various frequency and source position. CBF method was mainly used for data analysis. Test results were compared with simulation results. Test results shows that there are errors in source poisoning under certain frequency region. The critical frequency from test results is inside the band of 1 & 2 wave length of maximum phase difference for all source position.

1 INTRODUCTION

The beamforming method for noise source identification in space is one of the most powerful techniques in acoustic wind tunnel tests. Many remarkable progresses such as 'Diagonal removal'[1], 'Moving source'[2], 'Deconvolution approach'[3] are achieved for beamforming over the past years. But, there are still some problem(array pattern dependency, coherent source, reflection environment etc) which have to be solved to use the beamforming method more wide fields. This paper deals with the reflection environment problem.

The acoustic test results in the environment like closed test section may interfere with the reflected sources. S. Guidati proposed the reflection canceller to correct the hard wall effect[4]. P. Sijtsma shows that the magnitude of source from conventional beamforming analysis(CBF) has fluctuating error at low frequency region[5]. B.A. French proposed the image source model for closed test section. The reflected source effect is not severe in high frequency region, so the acoustic test for small scaled model could be conducted in closed test section. But, for large scaled model like UAV the reflected source effect should be considered.

A series of acoustic test with point source was conducted in KARI low speed wind tunnel with 4mx3m closed test section to find out the reflected source effect. The microphone array with 144 channels was used and B&K 4295 speaker was used for noise source. The test was conducted with various frequency and source position. CBF method was mainly used for data analysis. Test results were compared with simulation results. Test results shows that there are errors in source poisoning under certain frequency region.

2 WIND TUNNEL TEST

2.1 Test setup

KARI low speed wind tunnel with 4x3m closed test section was used for this test. The array of 1m diameter with 144 microphones(RTI 1207A) was used which was mounted on the center of bottom wall. The B&K 4296 speaker and Agilent33220A signal generator was used for noise source. The axis system; X-axis is wind direction, Y-axis is tunnel width and z-axis is tunnel height. The side wall is positioned at -/+2m in Y-axis. The source position was changed from 0 to -1.59m in Y-axis. The height of source from the array is 1.07m for all tests. The source frequency was changed from 0.5kHz to 8kHz. VIPER from Gbmh with 144 channels was used for data acquisition system. The sampling rate is 25.6kHz and the duration is 4sec. The array calibration was done with burst signal and the maximum delay between the microphones is less than 15usec. The array center position is {-1.870, 0,-1490}.

2.2 Test results

Conventional Beamforming(CBF) techniques was used to process the data. Acoustic images are shown in Fig. 2 ~ Fig. 3. The contour is 0 to -6dB reference with maximum value. The source position has large error in 500Hz and very accurate in 4000Hz. The source position error in Y-axis was calculated for all frequency. This is shown in Fig. 4. The error is increased when the source approach the side wall. In Fig. 4 we can find that the position error doesn't occur above certain frequency.

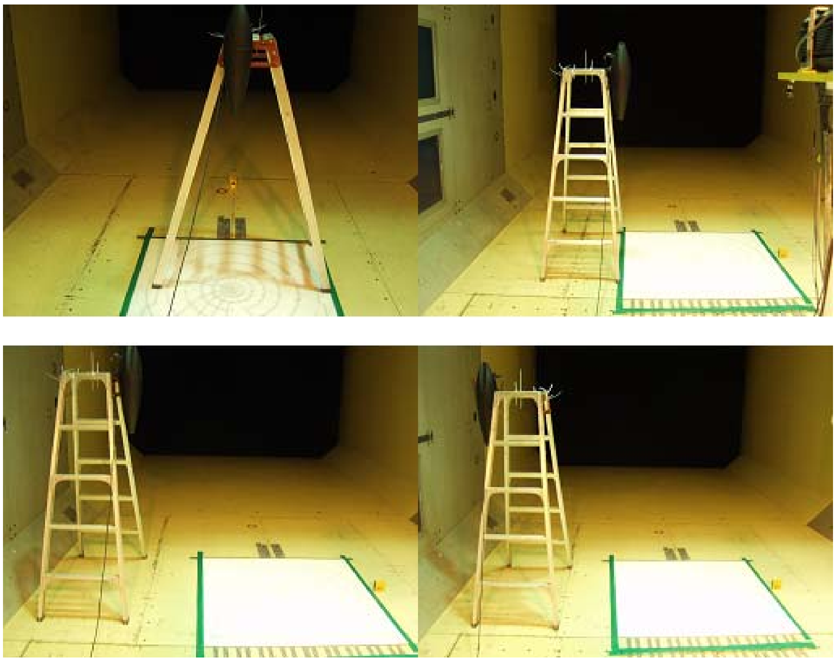

Fig. 1. Noise source measurement with B&K 4295 speaker in KARI LSWT.

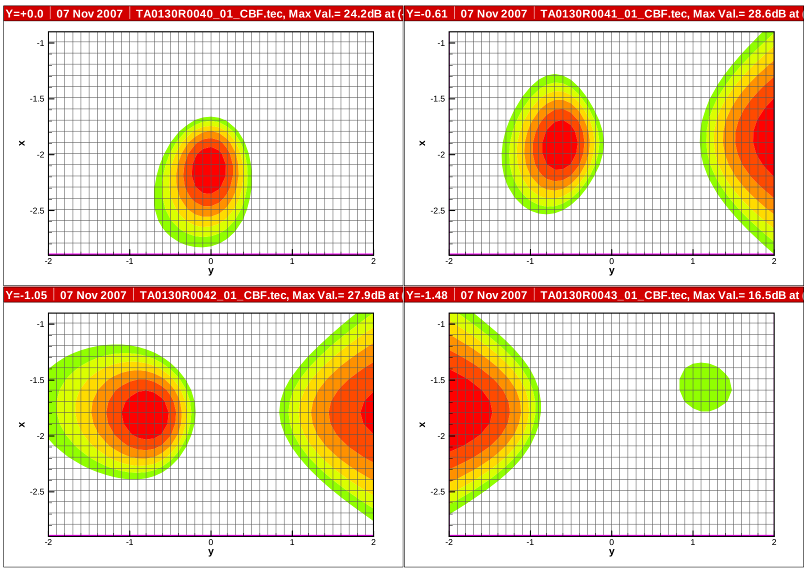

Fig. 2. Acoustic images by CBF : Source frequency=500Hz. Source position : y=0, -0.61, -1.05, -1.48m from left-top clockwise direction.

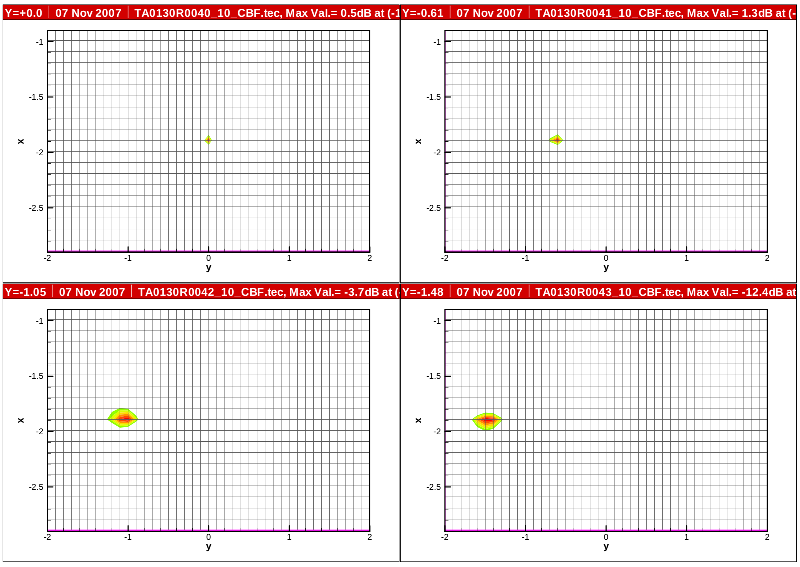

Fig. 3. Acoustic images by CBF : Source frequency=4000Hz. Source position : y=0, -0.61, -1.05, -1.48m from left-top clockwise direction.

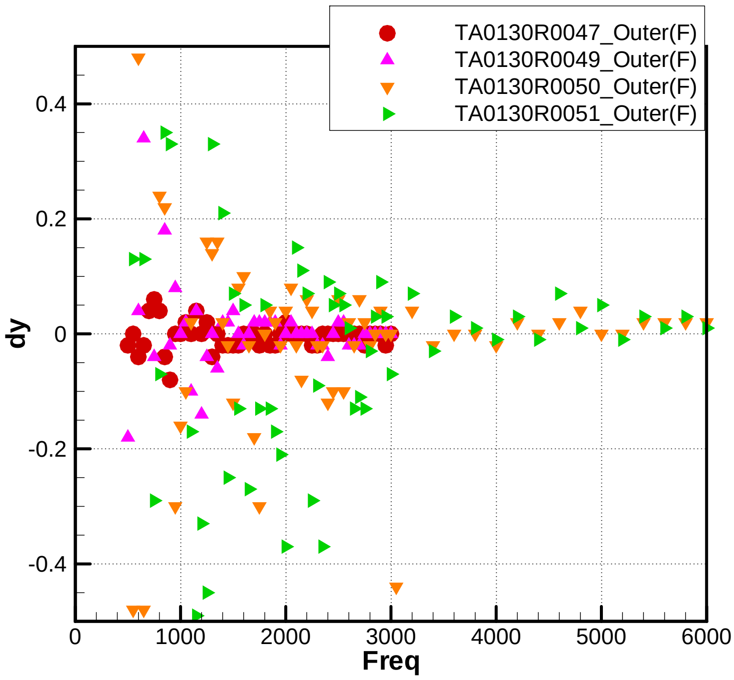

Fig. 4. The source position error in Y-axis : R0047(Y=0), R0049(Y=-0.74), R0050(Y=-1.18), R0051(Y=-1.47).

2.3 Simulation

Computer simulation was conducted for same case with wind tunnel test. Monopole point source was used for noise source and virtual wall was simulated by using image source. Simulation was carried for 1-side wall case and 4-side wall case. CBF processing techniques was used also. The source position error was found in simulation for all cases. But the error depends on the order of image for 4-side wall case. The position error for 1-side wall case was compared with wind tunnel test results. This is shown in Fig. 5. Red line is simulation results and blue dot is wind tunnel test results. The 1-side wall simulation results shows similar position error with wind tunnel test results.

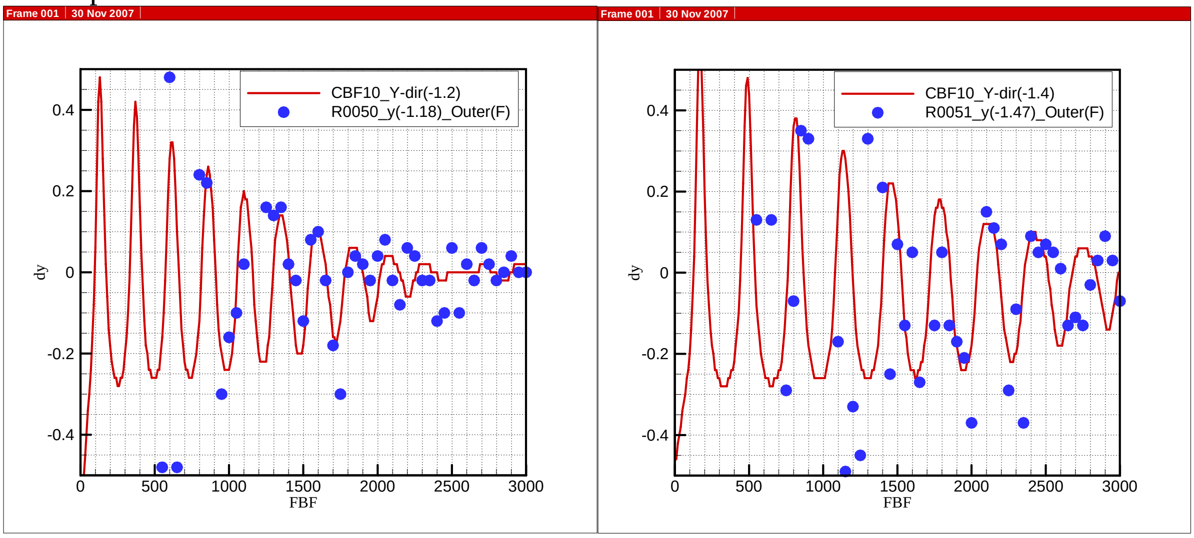

Fig. 5. Comparison of wind tunnel test result with simulation for the position error.

2.4 Critical frequency

Simulation and wind tunnel test results shows that there is critical frequency that decide the region in which the reflected source has strong effect to source position. The minimum condition to cancel out the reflected source signal in CBF process is that the maximum phase difference of reflected source signal in the array microphones should be larger than one wave length. Under script '0' denotes original source, '1' denotes reflected source and 'c' denotes critical frequency in eq. (1). The frequency for which the maximum phase difference is 1 wave length, 1.5 wave length and 2 wave length was calculated for the source position is 0 to -1.9m. And the critical frequency in test results was defined as the source position error is less than 0.05m above the critical frequency. This is shown in Fig. 6. The critical frequency is inside the band of 1 & 2 wave length for all source position.

$$
\begin{aligned}
&b = |< w^* p >|^2 = |B|^2 \\
&B = \sum_{m=1}^{M} \left\{ \frac{1}{r_{0;m}} + \frac{1}{r_{1;m}} e^{i\frac{\omega}{c}(r_{1;m} - r_{0;m})} \right\} = B_0 + B_1 \\
&B_1 = \sum_{m=1}^{M} \left\{ \frac{1}{r_{1;m}} e^{i\frac{\omega}{c}(r_{1;m} - r_{0;m})} \right\} = \sum_{m=1}^{M} \left\{ \frac{1}{r_{1;m}} e^{i\frac{\omega}{c}\phi_m} \right\} \\
&\phi_{m:c} = \frac{2\pi f_c}{c}(r_{1;m} - r_{0;m}) \ \ ; \ \Delta\phi_{\max} = \max(\phi_{m:c}) - \min(\phi_{m:c}) \geq 2\pi
\end{aligned}
\tag{1}
$$

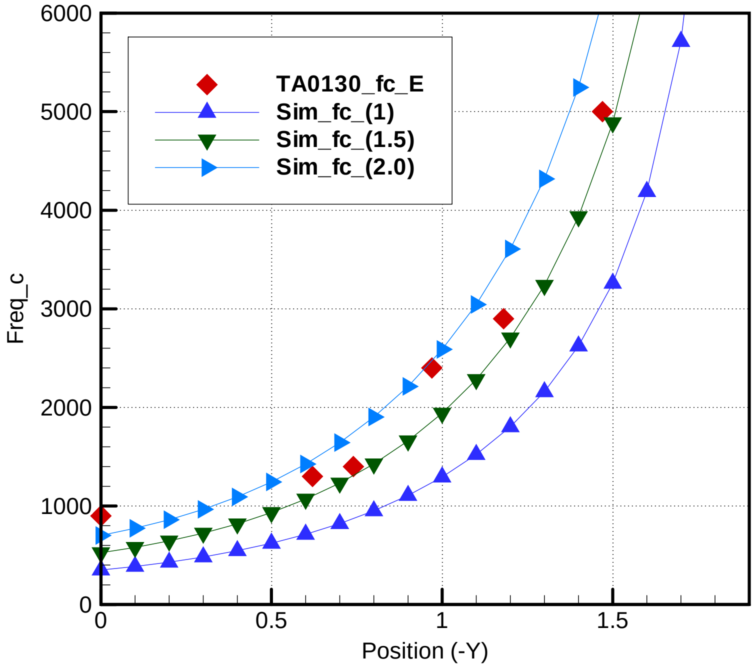

Fig. 6. Comparison of critical frequency(red dot) with 1wave length(blue), 1.5 wave length(green) and 2 wave length(cyan).

3 SUMMARY

The reflected source effect in closed test section was researched in KARI LSWT. Test results was compared with 1-side wall simulation results. The source position error occurs under the critical frequency which can be calculated from maximum phase difference in the array. The critical frequency can be used to decide the model size and test frequency.

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